

THE TROPENAS CONVERTER STEEL PROCESS.

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In any process for the manufacture of steel, it is necessary to realize certain practical conditions if the process is to be a commercial success. These conditions are: 1st. Regularity of the operation. 2nd. Regularity and absolute control of the quality of the steel.

During recent years many processes for manufacturing steel by means of small converters have been introduced. They have been tried industrially and in most cases abandoned because the extraordinary advantages claimed for them by their inventors have not materialized in practice or have proven to be greatly exaggerated. The failure of nearly all of these processes to realize the absolutely necessary conditions of practical metallurgy has brought into existence a considerable prejudice against the use of small converters and many manufacturers have come to the conclusion that it is impossible to make a good product in such a way.

The Process that has been introduced into this country and which forms the object of this paper, possesses the above mentioned features in a high degree, and the results obtained are not based upon mere experiments but on a practical working of over nine years.

The first converter used was of a capacity of about 800 lbs. and was erected in 1891-2 in the works of Edgar Allen & Co., Ltd., Sheffield, England.

The trials made with this experimental vessel were so satisfactory that after a few weeks the above named firm decided to build a two-ton converter.

The results obtained were exactly those anticipated, and since then two other two-ton converters have been erected. This firm has now three two-ton converters with which all its castings are exclusively made. The output of the works at the pres-

ent time is over 9,000 tons per year. Other plants have since been erected in most of the countries of Europe and three years ago the first vessel was erected in the United States. Some twenty Tropenas plants with over fifty converters are now running in Europe and nine plants with thirteen converters are now running in the United States and Canada.

In all of these works the manufacture of general steel castings for machinery and electrical purposes has been carried on with great success, fulfilling all the physical and chemical requirements. Some ingots have also been made as well as anvils, hammers and similar articles. Steel castings have been made in some recent plants for the United States Government and from the published test tables it can be seen that the material was accepted and of first quality. The ultimate strength is 65,000 to 73,500 lbs. per square inch. The elastic limit 30,000 to 38,000 lbs. per square inch. The elongation in 2 inches, 27 to 37 per cent., and the reduction in area 45 to 57 per cent.

Dynamo Magnet steel of extreme purity and permeability can be made with absolute regularity and tests made both in Europe and here show that the product has a permeability not equalled by steel made with any other process.

Large or small castings can be made at will. Small and medium castings are specially made with great facility, sound, free from blow holes, and of a high physical quality. The manufacture of these small and medium castings take in a field which heretofore it has not been possible to cover with other known steel processes. Though one is specially enabled to make small castings with success, the Tropenas Process is also well adapted for large castings weighing up to ten tons. This can be done by running two two-ton converters alternately and collecting the steel after each operation in a ladle until the required amount is reached. This is made possible owing to the great heat and consequent fluidity of the metal. It has been found in past years that even with obsolete types of cranes and foundry appliances five or six blows could be collected in this way and afterward poured over the lip of the ladle, leaving no skull. To-day with modern foundry machinery, especially cranes, it is possible to make much heavier castings with a double two-ton plant. Castings up to 5 tons can be made with one two-ton converter in the same manner. The first and second heats will remain hot long

enough to accomplish this and it frequently happens that castings are made with steel a portion of which has remained in the ladle for more than two hours.

The Tropenas Process consists of a special converter in which iron, melted in a cupola beforehand, is converted into steel. This vessel like all other converters is a sheet steel shell lined with silica bricks or ganister. The shell is fitted with two hollow trunnions carried on pedestals so that the apparatus may be tilted according to the requirements of the operation, i. e., charging the molten iron, pouring the steel, etc. The interior of the converter, is so designed that the metallic bath has a much greater depth than in all the other pneumatic processes. The blast enters the converters from the pressure blower through the trunnions, feeding the wind boxes and tuyeres—which direct the air over the metallic bath. The pressure and volume of air are regulated by suitable valves.

Before commencing operations the converter is heated by means of coke or crude oil, afterwards no fuel is needed in the converter as it is supplied by the metalloids in the iron which are to be eliminated. The pig iron and steel scrap having been melted in a cupola or other furnace is run into the converter; the position of the converter relative to the level of the metal is then adjusted so as to have the proper conditions for blowing. The blast is started and at a certain period of the operation supplementary blast is introduced at will by means of the auxiliary tuyeres. This completes the combustion of the escaping gases, raising the temperature of the bath by radiation. At the end of the operation a bath of very fluid and soft metal is the result and recarburization is made in the vessel or in the ladle as in other steel processes. By varying the final additions steel of any desired hardness or quality may be produced exactly.

The Blast pressure required varies between 3 and 4 pounds per square inch according to the kind of pig iron treated. The blast can be produced by means of a blowing engine or a positive pressure rotary blower.

By what has been said above it is apparent that the characteristic features of the Tropenas Process are the following:

- 1st. Low pressure blast, always above the surface of the metal.
- 2nd. Special disposition of the tuyeres in the horizontal

plane so that the jets of air will enter into the converter above the bath and will not impart to it any gyratory or tumultuous motion whatever.

3rd. Great depths of the metallic bath so as to avoid churning and stirring during the operation. The result is that the steel contains very little occluded gas and therefore pours quietly into the molds, producing castings free from blow holes.

4th. Arrangement above the "fining tuyeres" and independent of the latter, of auxiliary or "combustion tuyeres," so as to burn the combustible gases which escape from the bath and which in all other pneumatic processes pass unconsumed up the chimney. The combustion of these gases increases the temperature of the bath by radiation very considerably. This makes the subsequent manipulation of the steel in pouring, etc., much easier and more satisfactory. As many as 150 molds have been poured from a heat of about 3,500 lbs., with bull ladles, holding about 125 lbs. each. In making large castings it is often necessary to add cold scrap to the steel in the ladle or let it stand exposed to the air some minutes to cool before pouring.

By the use of auxiliary tuyeres the carbonic oxide arising from the bath is transformed into carbonic acid gas. By burning these gases in a practical manner, which in all the other processes are discharged without burning into the atmosphere, as stated above, the temperature of the final steel is much increased without any additional cost.

Every practical foundryman knows that the best results are obtained with metal suitable in temperature for the class and weight of the castings to be made.

The Tropenas Process has this advantage that being so very hot at first, a great number of the lightest castings can be poured just before the steel commences to get thick, and then the larger castings are taken care of. Using always lip pouring ladles for large and small castings alike, one is able to judge from the surface of the metal its suitability as to temperature for any purpose.

Though the metallic bath is practically quiet during the operation, the reactions caused by the fining blast are quite sufficient to secure a perfect homogeneity of the charge. This is clearly demonstrated when we pour a two-ton heat into bull ladles for small castings. The steel as shown by analysis is found to be absolutely the same from the first to the last ladle.

The handling of the converters is not difficult. A chemist or a foreman can be taught in a few weeks how to work the apparatus properly. As in all other systems, however, a good knowledge of metallurgical chemistry is of the greatest assistance, and it and such assistance by a competent chemist will always prove economical.

The loss of metal during the operation, including cupola and converter is about 17 per cent. It varies 1 to 2 per cent., according to the kind of material used and the ability of the melters. This is not excessive if it is considered that the loss in cupolas alone is generally from 5 to 7 per cent., and that the iron to be treated usually contains from 5 to 7 per cent. silicon, carbon and manganese to be eliminated. It is scarcely correct to speak of the removal of these elements as a loss, for while being eliminated they serve the useful purpose of raising the temperature of the bath, thus doing away with the necessity for any other additional fuel, as previously stated.

The pig iron used for the production of steel castings analyses as follows:

Silicon,	2.00—4.00 per cent.
Manganese,	0.50—1.25 per cent.
Carbon,	3.00—4.50 per cent.
Sulphur,	up to 0.06 per cent.
Phosphorus,	up to 0.07 per cent.

The lower the sulphur and phosphorus the better the results. When the steel produced is to be submitted to particularly severe tests, it is better to use pig iron as low in sulphur and phosphorus as possible.

One can usually find pig iron here with Sulphur 5.015 per cent., Phosphorus 0.03 per cent., and the steel made from it will run below 0.05 per cent. in phosphorus. However, when the requirements are only those for the machinery trade, iron up to 0.07 per cent. of phosphorus can be used.

The sands required for making molds are the same as used in other steel foundries and the molds are dried or not according to the kind of castings to be made. Many small and medium castings are made in green sand molds.

The steel as it comes from the sand is perfectly soft and

malleable. The great majority of the castings delivered to the machinery trade are neither reheated nor annealed. Where castings, however, have great or uneven thicknesses or when they are intended for special purposes it is sometimes necessary to anneal them. The object of this annealing being to simply transform the crystalline structure or to relieve the molecular tension due to shrinkage. Tests made on unannealed pièces have



shown that in many cases annealing is entirely unnecessary.

The installation of the steel Process proper requires first, one or several converters according to the quantity of steel to be produced. Each converter works usually in connection with a cupola.

The cupola is operated in the usual manner, the depth below the tuyeres is greater than in the ordinary cupolas, so as to hold more metal in the well. A fan or blower is used to supply

blast. The air blast for the converter is usually produced by a positive pressure rotary blower.

The final additions for the converter are metled in a crucible furnace or a small cupola.

Besides the above mentioned apparatus the usual foundry equipment of cranes, oven, flasks, ladles, etc., is necessary. The better a foundry is equipped the cheaper are the castings, and it



would be useless to build a foundry and put in converters to turn out large quantities of steel when the equipment to take care of it is not sufficient to handle it quickly and cheaply.

Each operation in the converter lasts from 12 to 20 minutes. The time required for pouring the steel into the ladles and preparing the converter for another blow varies according to the style of castings made. Whenever small castings are manufactured and the whole charge has to be poured into hand ladles,

40 minutes is required for a complete operation. When the pouring is done with large ladles only 30 minutes are required. In the first case 10 blows, equivalent to 20 tons of steel, can be made in 7 hours. In the second case 10 blows, equivalent to 20 tons of steel, can be made in 5 hours.

One of the foundries using this process recently stated that they had made 11 blows in an average of $25\frac{1}{2}$ minutes per blow with one 2-ton converter.

The tuyeres used last on an average 30 operations without renewal. With proper care they can be made to last longer. If a large number of operations are carried on at one time, and work is continuous as possible with the same converter, the lining will last longer than with intermittent operations. Usually patching is begun after 20 blows, keeping this up and making about 150 blows before removing the tuyere and setting a new one. The linings are made with silica brick or ganister. The tuyeres are made in blocks of practically the same material as the lining.

The cost of producing steel varies with the price of raw materials, the out-put, and the foundry appliances. One can, therefore, only give a rough estimate based upon the practical experience of modern foundries.

If the price of pig iron is \$17.00, the waste being estimated at 17 per cent., the cost of the steel will be: \$17.00 divided by 83 plus proportional expenses of all other material, plus labor charges.

The proportional expenses include all raw materials used in the production of the steel, coke, ferro's, bricks, chemicals, etc. The labor includes that at the cupola and the converter, the chemist, etc.

For an out-put of from 300 to 400 tons of steel per month, necessitating 3 two-ton converters, labor and raw material taken at present prices, the proportional expenses alone will be about \$4.70 per ton and the labor \$1.80 per ton. Total cost will be about \$17.00 divided by 83 plus \$4.70 plus \$1.80; or \$26.98 per ton.

For an output of 200 to 300 tons of steel per month the total cost would be \$17.00 divided by 83 plus \$4.75 plus \$2.45; or \$27.68 per ton. For an output of 100 to 200 tons per month, necessitating two two-ton converters, it would be \$17.00 divided

by 83 plus \$4.75 plus \$3.57 equals \$28.80 per ton. For an output of 70 to 100 tons of steel per month, necessitating one two-ton converter, the cost would be \$17.00 divided by 83 plus \$4.80 plus \$6.20 equals \$31.48 per ton. It is impossible to figure how much the steel would cost for a smaller output because the labor would become too uncertain a factor.

So far as Blow Holes are concerned it may be said that if they are found in the castings it is attributable to defective molds or to the manner of casting. When the molds are properly prepared and dried and the metal is poured as it should be, the castings are free from blow holes.

Fifty thousand tons of steel castings per annum are now produced by the Tropenas Process, and the marked favor with which they have been received everywhere shows that they give satisfaction and are successfully meeting all the requirements of the trade. The castings of ordinary soft quality weld as well as the best soft steels. If it is admitted that wrought steel, which after welding, still has 70 per cent. of its original tensile strength, is considered excellent, the two appended tests show that this steel is of very fair quality.

Condition.	Elastic. Limit.	Ultimate Strength.	Per cent.	
			Per cent. Elongation.	Reduction In Area.
Unannealed,	30,060	56,550	21.00	22.29
Cut and welded, . . .	37,360	58,947	11.00	30.60
Forged,	36,330	64,445	33.00	50.70
Annealed,	32,200	69,000	32.50	44.20
Forged,	46,850	79,750	24.00	51.10
Cut and welded, . . .	45,250	63,700	5.00	2.60

The Tropenas Process now introduced in this country has proved to be all that was claimed for it, 9 plants are in operation here and contracts for two others placed, one of which is almost completed.

There seems to be a great future before the Process in the manufacture of specialties for which it is particularly well adapted. There has been considerable controversy as to the quality of Tropenas steel. Some people say that it was as brittle as cast

iron; others that it was the best steel they ever saw. Those who understand the manufacture of steel castings will be able to judge best. With the best material it is possible to make the worst product, if not manipulated properly. It is very encouraging, however, to note how seldom raw material is spoiled in the handling even by men of very little experience. Failures have happened no oftener in this Process than in any other, even in those in which operators have had much more experience.

The steel molder has been accustomed to see the steel castings come out of the sand pretty rough. This is due to the physical or chemical action of the metal upon the face of the mold and also from the fact that molds are often prepared with a rough surface. If hot steel is poured into a smooth mold, gated properly, and made with sand of the right quality, there is no reason why the castings should not come out nearly as smooth as a gray iron casting.

The steel should not be poured too hot because the shrinkage will be necessarily greater and the chances are that the casting may be spoiled through shrink holes or pulling apart.

It is an easy matter to get steel cold enough, so that whenever a casting is spoiled on account of being poured too hot it is the fault of the men who cast. This is sometimes the case in plants when the men have no experience with Bessemer steel, and it is probably the reason why the open hearth men get the poorest results with this steel at the beginning.

Usually the open hearth men pour the steel, when using that process, into the mold whether hot or cold, for they cannot ascertain its state before pouring on account of using bottom pouring ladles. Moreover the amount of metal to be distributed in one heat is so great that the pouring must proceed without delay in order to get the steel out of the ladles before it chills.

Tropenas steel foundries, on account of the amount of steel handled at one time, and the way in which it is manipulated, are comparable to iron foundries. We see the surface of the steel before pouring and can tell whether it is fit or not to go into a mold. With a good foundry equipment and men handled properly the best castings can be made.

In conclusion reference is again made to the special suitability of this steel for electrical purposes. There is no process known which makes dynamo and general electric castings so

satisfactorily. It is very easy to make them with the closest regularity. The chemical analysis of this steel is approximately: Silicon, 0.04 per cent.; Manganese, Trace; Carbon, 0.09. Sulphur and Phosphorus according to the quality of the raw material.

The total iron in this material is from 99.70 per cent. to 99.80 per cent., that is to say it is practically wrought iron, free from slag. To produce this material in a manner enabling it to be handled and poured into the molds requires an exceedingly high temperature. Large quantities of magnet steel castings are now made in this country and it is hoped that Electrical Engineers will soon appreciate the advantages offered by this method.

This process recommends itself especially to cast and malleable iron founders, who may wish to substitute steel for these metals as it only requires an additional installation of a converter and its accessories, at a cost not excessive. That the tendency of the trade is to substitute steel for cast iron in some measure will not be denied as with a slight additional cost a metal can be made which will offer a superior strength not obtainable by cast or malleable iron. Moreover steel being so much stronger castings can be made much lighter and cost but little more owing to the reduced weight. From the fact that a sound steel is obtained the machinist is saved such labor as is expended in machining castings which often times do not show their blow holes and defects until after much money has been lost.

This Process, unlike the open hearth, permits intermittent operations as the heating of the converter is cheaply accomplished. According to the demands of the market the foundryman can work his converter continuously or he may discontinue its use until he has again gathered a sufficient number of molds to warrant him to fire again, exactly in the same conditions as melting with a cupola. In casting, owing to the great fluidity of the metal, but very small headers or risers are required.